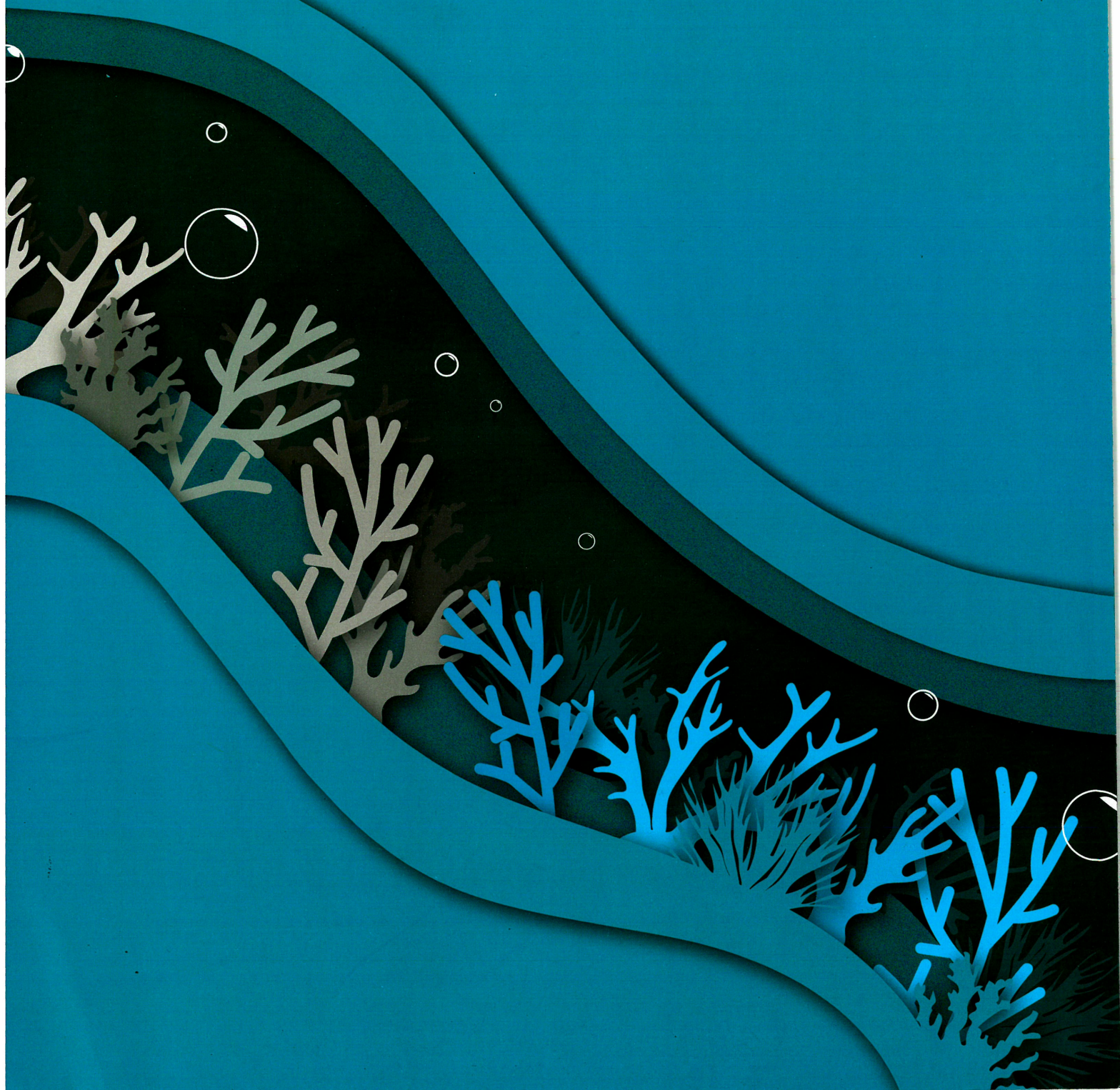


CRITICAL CARE MEDICINE 1

Marrow SS Medicine





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Critical Care Medicine

Volume - 1

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HEMODYNAMIC MONITORING

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Cardiovascular organ dysfunction : 2nd most common organ dysfunction.

Continuously observing changes in physiologic variables :

- To monitor organ function.
- For prompt therapeutic interventions.
- To evaluate response to therapeutic interventions.

monitoring per se does not improve patient outcomes.

Timely applied right interventions can cause improvement in outcomes.

Assessing global and regional perfusion

00:01:19

Initial steps :

1. Clinical assessment.
2. Basic monitoring and assessment of global perfusion.
3. Preload monitoring and fluid responsiveness.

Advanced monitoring measures :

1. Cardiac output monitoring.
2. Assessment of cardiac contractility.
3. Assessment of tissue perfusion.

Step 1 : Clinical assessment.

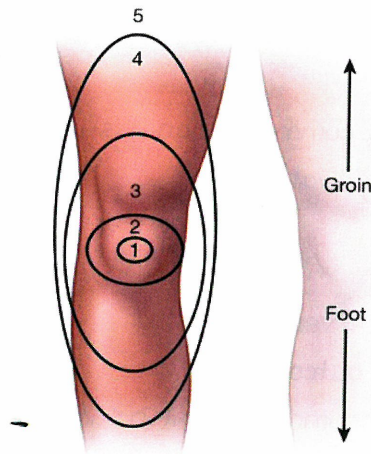
- | | | |
|---|---|--|
| <ul style="list-style-type: none"> • Thirst. • Cold extremities. • Poor peripheral pulses. • Impaired capillary refill. | → | <ul style="list-style-type: none"> • Tachypnoea, tachycardia. • Confusion. • Altered skin perfusion. • Oliguria. |
|---|---|--|

Skin mottling :

Important predictor of adverse outcome.

- Score 0 : No mottling.
- Score 1 : Small area of mottling, localised to centre of knee.
- Score 2 : modest mottling area that does not extend beyond superior border of kneecap.
- Score 3 : mild mottling area that does not extend beyond the mid-thigh.
- Score 4 : Severe mottling area, not going beyond the groin fold.
- Score 5 : Extremely severe mottling area, extending beyond groin fold.

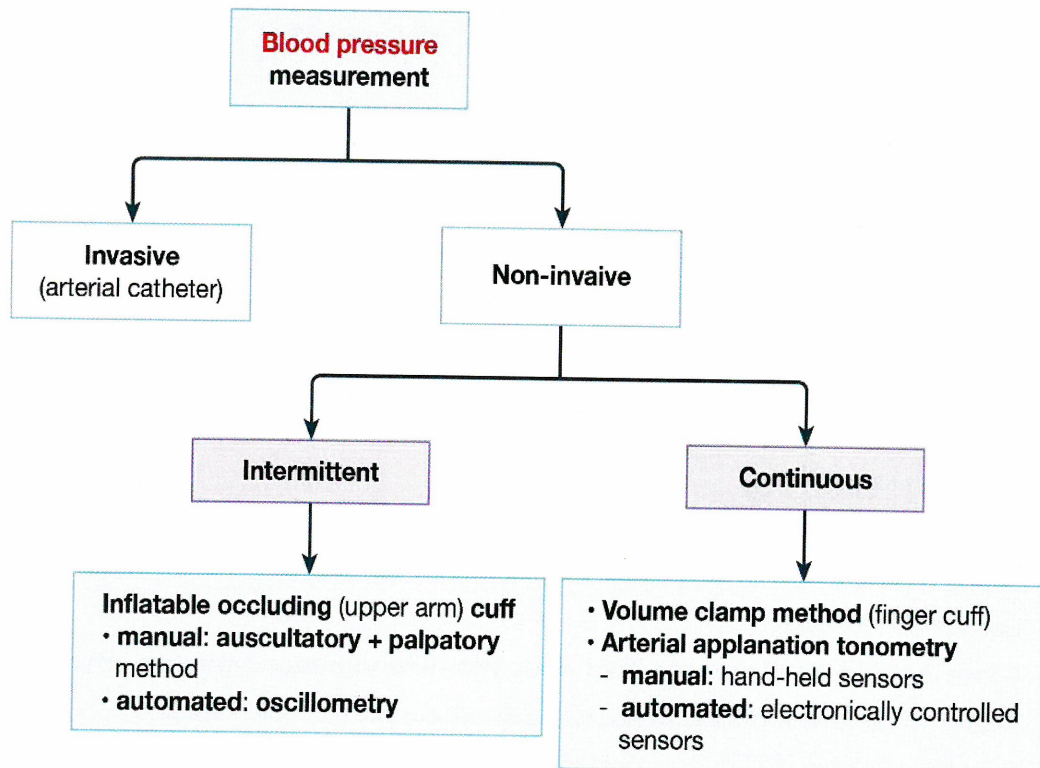
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Mottling score

GRADE 2 MOTTLING

**Step 2 : Basic monitoring and assessment of global perfusion :**

- 12 lead ECG.
- Blood pressure : Non invasive and invasive.
- Pulse oximetry (SpO_2).
- Lactate levels.
- Biochemical variables.

Blood pressure monitoring :

NIBP : Intermittent.

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manual intermittent	Automated intermittent
<ul style="list-style-type: none"> Described by Korotkow in 1905. Sphygmomanometer, cuff, and stethoscope needed. Auscultating sounds generated by turbulent arterial blood flow beyond cuff. Systolic : First Korotkoff sound. Diastolic : Before disappearance. 	<ul style="list-style-type: none"> Based on oscillometry. Cuff is coupled to an oscillometer. The cuff inflated above systolic pressure → Then gradually deflates. MAP : pressure at peak amplitude of arterial pulsations. SBP & DBP : Derived from proprietary formulas (Rate of change of pressure pulsations).

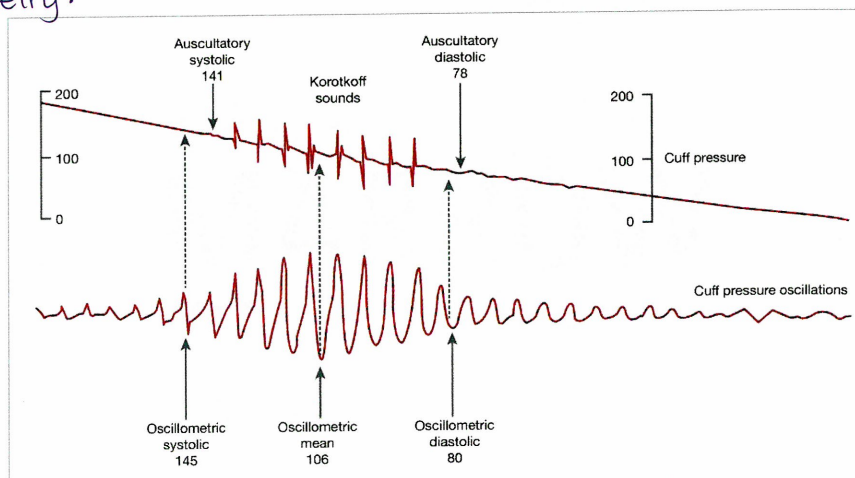
Cuff size :

- Bladder length : 80% of arm circumference.
- Bladder width : 40% of arm circumference.
- midline of cuff bladder should be positioned over the arterial pulsation.

Patient	Recommended cuff size
Adults (by arm circumference)	
22 to 26 cm	12 x 22 cm (small adult)
27 to 34 cm	16 x 30 cm (adult)
35 to 44 cm	16 x 36 cm (large adult)
45 to 52 cm	16 x 42 cm (adult thigh)

BP cuff size

Comparison of blood pressure measurements via Korotkoff sounds and oscillometry :



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Non invasive :

CNAP : Continuous noninvasive arterial pressure.

Volume clamp method (finger cuff) :

- Inflatable finger cuff with infrared
- plethysmography & monitor.
- Adjusts its pressure multiple times per second to keep volume in finger artery constant.
- Produce a brachial arterial waveform.



T- line system :

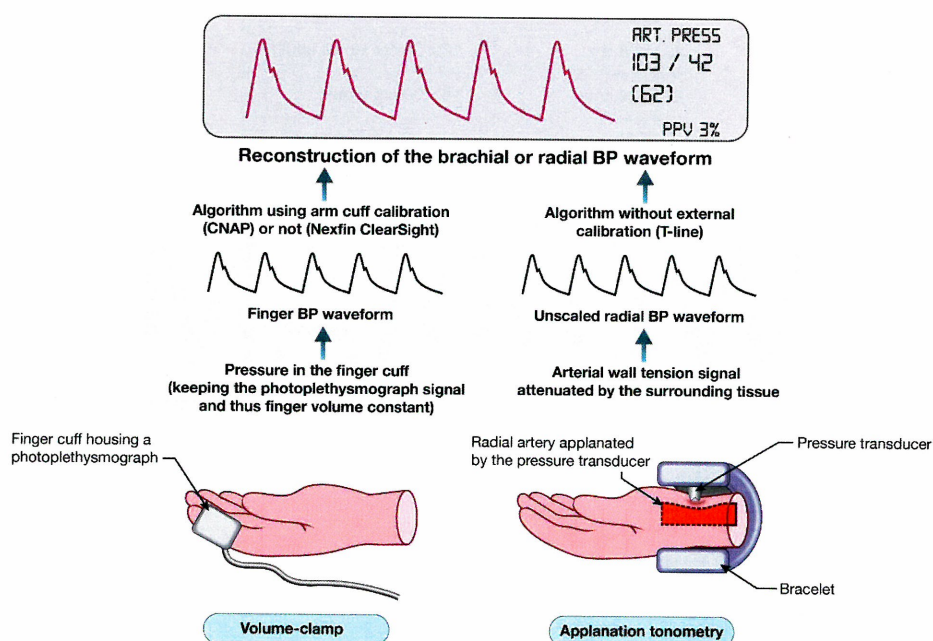
Based on applanation tonometry.

- Radial artery applanation :
- A pressure sensor applied over radial artery :
- Gently compresses artery : Applanates.
- The sensor is automatically moves over radial artery until optimal waveform is recorded.
- External applanation leads to reconstruction of BP waveform.
- mean BP measured directly (optimal waveform).

T- line system: Based on applanation tonometry



Oscillometric, volume-clamp, and applanation tonometry technol arterial BP



Invasive blood pressure :

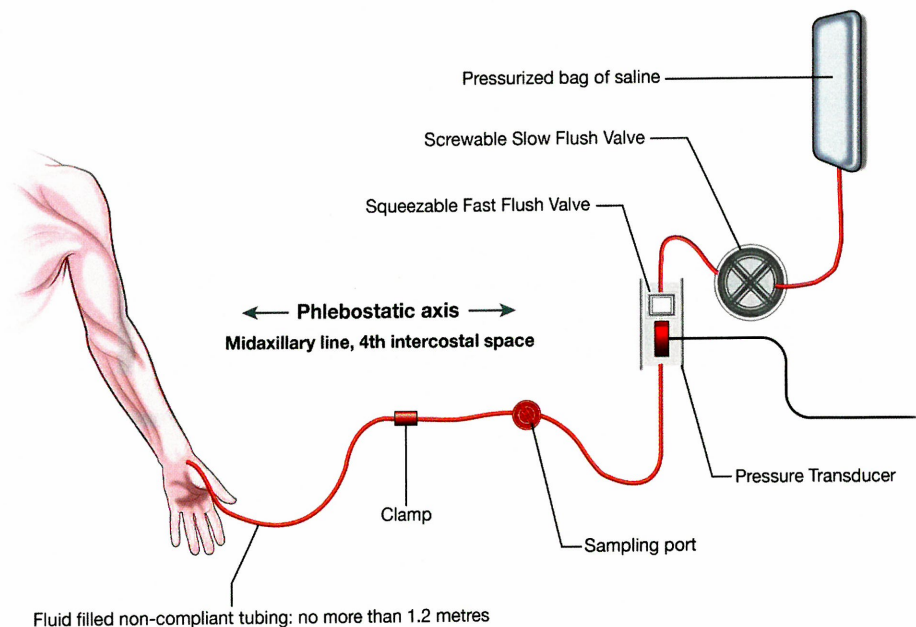
- Gold standard for BP monitoring :
 - Arterial cannulation.
 - Continuous pressure transduction.
 - Waveform display.

• Conventions :

- Pressures expressed as mmHg.
- Referenced to phlebostatic axis.
- Zeroed to ambient pressure.

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Arterial Line Transducer Setup



Indications :

- unstable blood pressure/severe hypotension.
- use of rapidly acting vasoactive drugs : vasodilators, vasopressors, inotropes.
- Frequent sampling of arterial blood.

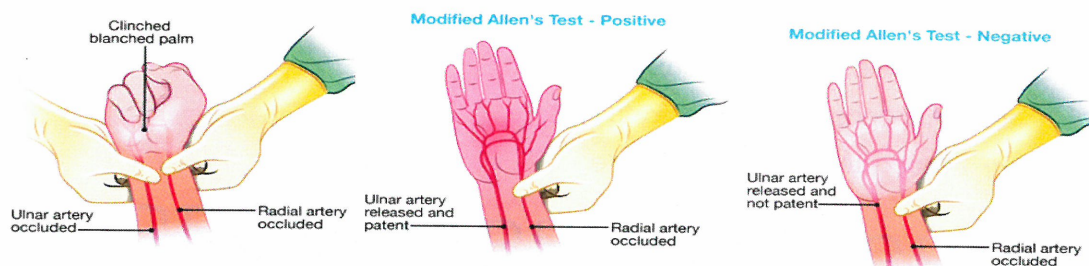
Relative contraindications for invasive arterial pressure monitoring :

- Anticipation of thrombolytic therapy.
- Severe peripheral vascular disease preventing catheter insertion.
- Vascular anomalies : AV fistula, local aneurysm, local haematoma, Raynaud's disease.
- Lack of collateral blood flow distally (Eg : Radial artery previously used for coronary artery bypass surgery).

modified Allen test :

- used to assess adequacy of collateral circulation.
- Reduced collateral flow when palm remains pale >6 to 10 seconds.
- Disadvantage : Sensitivity (70-80%).

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Common sites :

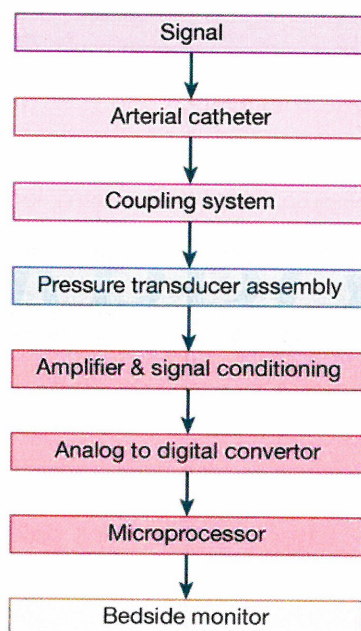
1. Radial.
2. Femoral.
3. Dorsalis pedis.
4. Posterior tibial.

Complications of direct arterial pressure monitoring :

- Distal ischemia, pseudoaneurysm, arteriovenous fistula.
- Hemorrhage.
- Arterial embolization.
- Infection.
- Peripheral neuropathy.
- misinterpretation of data.
- misuse of equipment.

Pressure monitoring system :

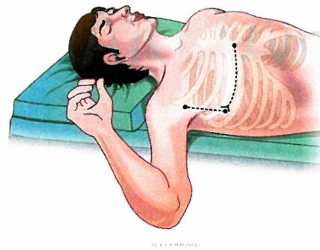
Pressure monitoring system



Zeroing & levelling :

- Levelling : At level of the right atrium, we establish the 0 baseline..
- Zeroing : Opening the transducer stopcock to atmosphere.
- Stopcock at level of midaxillary line 4th ICS :
Flavostatic axis.
- With the stopcock open, monitor displays 0.

Zeroing and Levelling



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Physics of arterial waveform

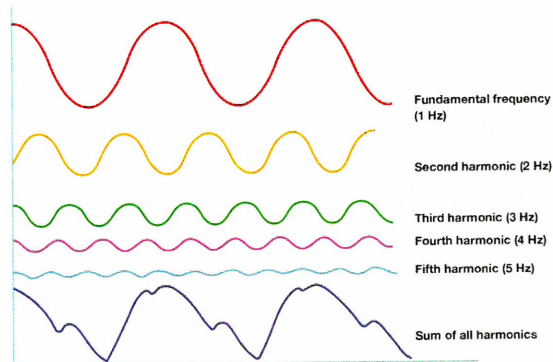
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Fourier analysis of complex waveform :

Arterial waveform is a composite of many waveforms of increasing frequencies (Harmonics).

8-10 harmonics.

Fourier analysis of a complex waveform



Natural frequency :

Frequency at which a system oscillates.

$$\text{Natural frequency } f_n = \frac{1}{2\pi} \sqrt{\frac{\pi D^2}{4\rho L} \cdot \frac{\Delta P}{\Delta V}}$$

Dependent on :

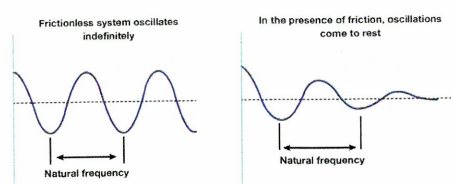
- maximum diameter.
- minimum length.
- Low compliance.

The coupling system :

Fluid between artery and transducer acts as simple harmonic oscillator :

- Analogous to a pendulum.
- When the pendulum is displaced, it undergoes simple harmonic motion it oscillates around the equilibrium point.

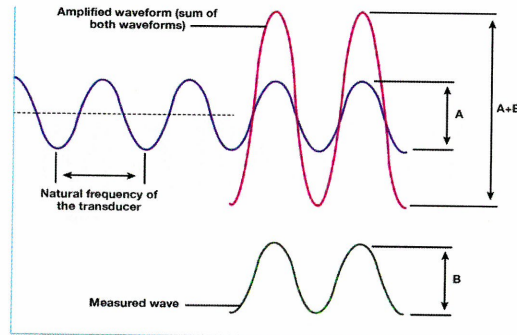
The Coupling system



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- Resonance : Amplification of a signal.
Occurs when it's frequency is close to natural frequency of a system.

The Coupling system



- If natural frequency of pressure transducer matches with each peak of arterial pressure wave \rightarrow Increase amplitude of the measured values.
- Transducer system must have a natural frequency well above the 8th harmonic frequency of a rapid pulse : **>24Hz** (Taking HR upto 180/min).

Damping :

- Absorption of energy (Amplitude) of oscillations :
 - Decreases amplitude of waves.
 - Reduces natural frequency of a system.
- Adequately damped \rightarrow Amplitude should not change due to resonance.
- Diameter of the tubing has the greatest effect on damping.
- Damping **increases by third power** of any decrease in tubing diameter.

Dynamic response :

Ability of the system to accurately reproduce hemodynamic waveform.

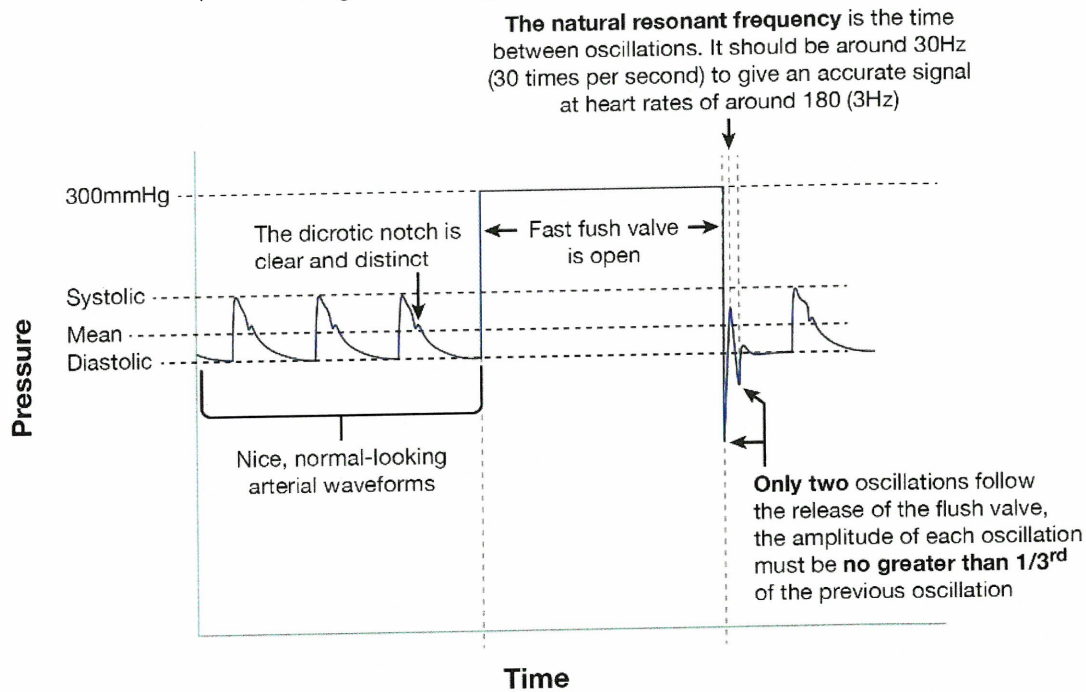
Damping coefficient :

To assess how quickly an oscillating fluid filled system comes to rest.

Test : **Fast flush test.**

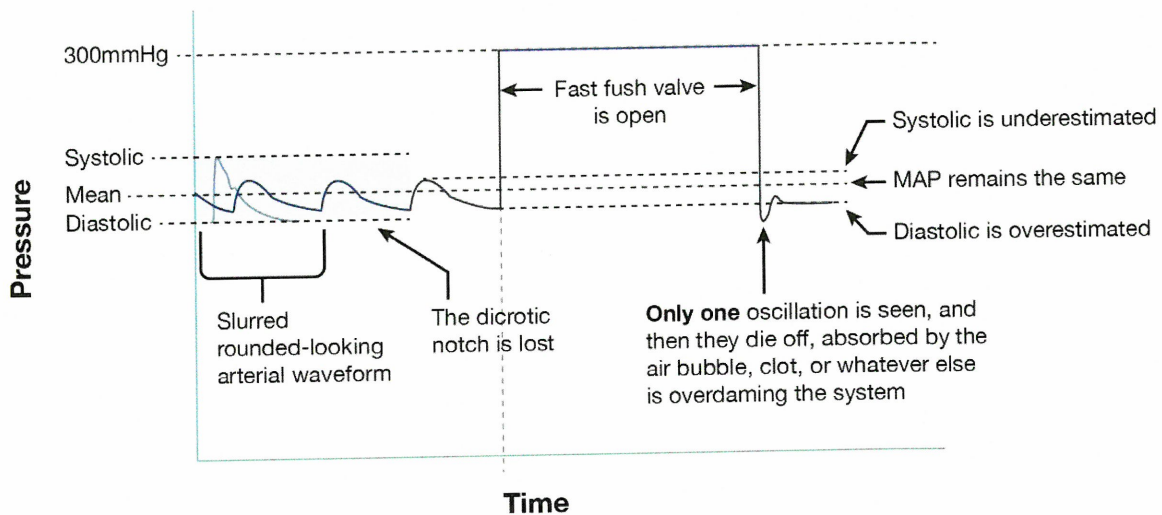
Arterial line setup : Damping adequacy.

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Over damped system :

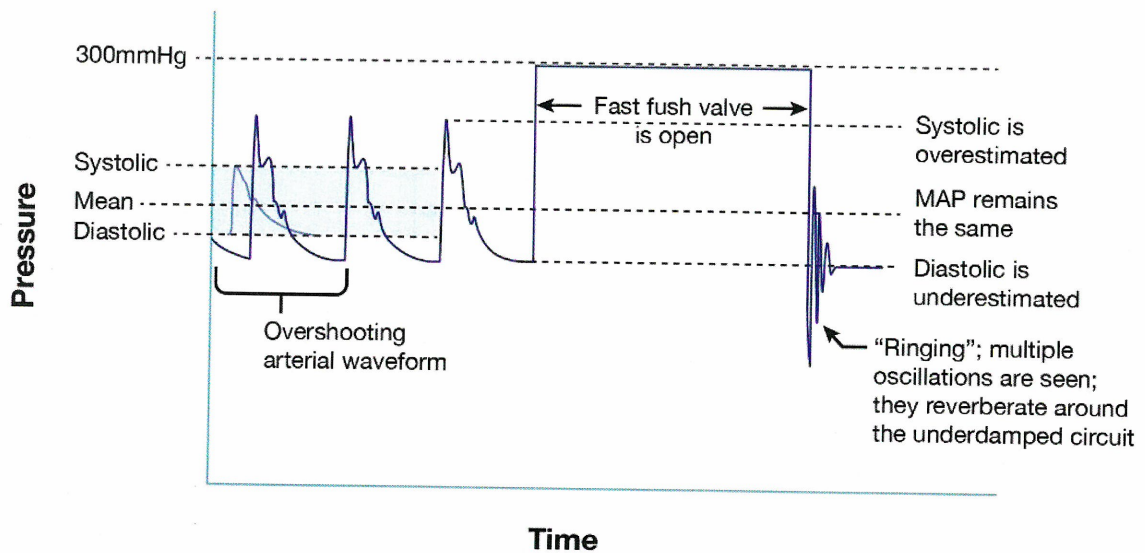
Arterial line setup: Damping adequacy



Occurs in cases of : Clots, kinks, air bubbles, low compliant tubings, loose connection.

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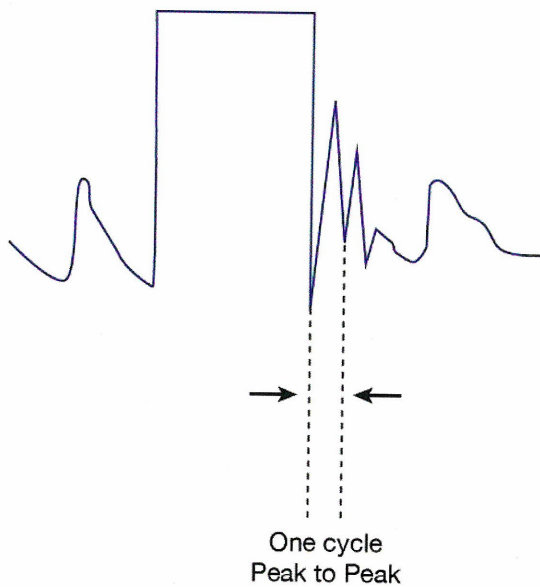
underdamped system :



Occurs in : Long tubing, hyperdynamic circulation, tachycardia, hypertension, atherosclerosis.

Determining frequency of a system :

Determining f_n



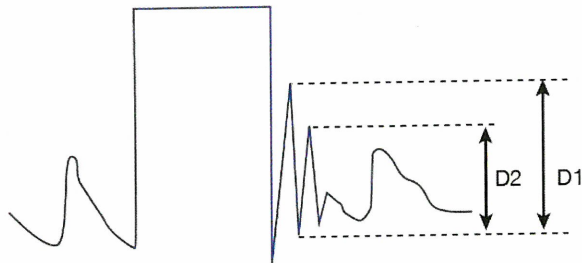
$$f_n = \frac{\text{Paper speed (mm/sec)}}{T \text{ (time of one cycle) mm}}$$

If $t = 1.2 \text{ mm}$, $f_n = 20\text{Hz}$

Amplitude ratio :

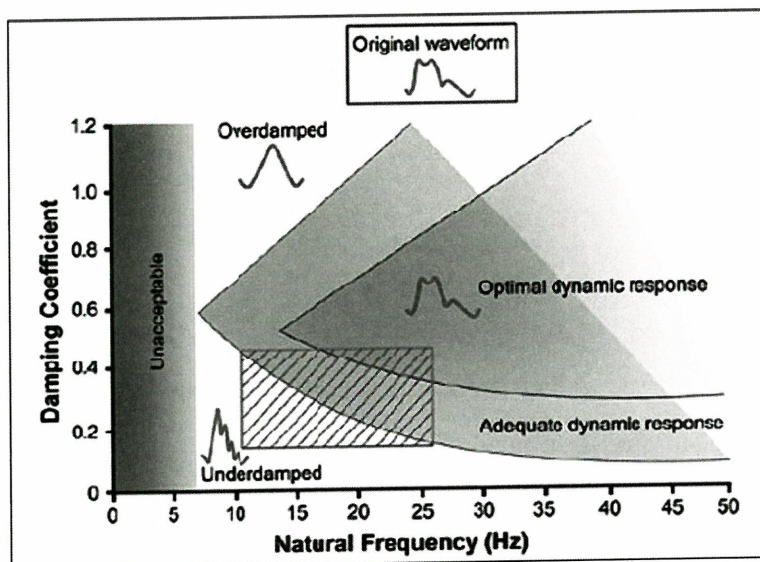
Height of waves generated following a fast flush test.

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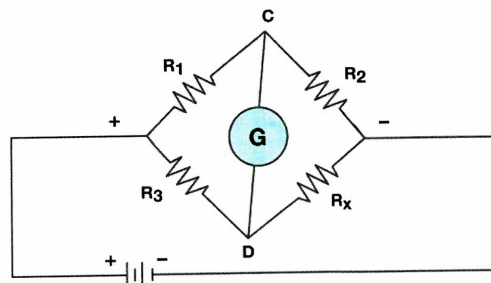
Amp Ratio (D2/D1)	Damping coefficient
0.9	0.034
0.8	0.071
0.7	0.113
0.6	0.160
0.5	0.215
0.4	0.280
0.3	0.358
0.2	0.456
0.1	0.591
0.05	0.690

Arterial line setup : Dynamic response.



Pressure transducer :

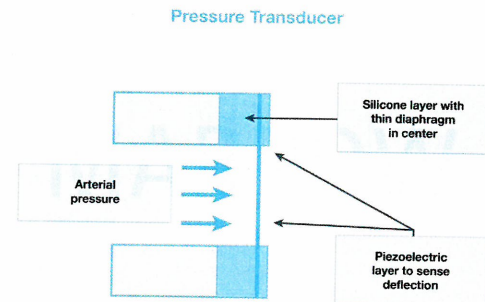
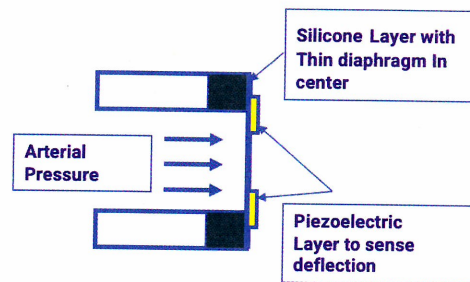
- A transducer is a device which converts energy from one form to another : Pressure into electrical energy.
- It acts on the principle of **wheatstone bridge**.
- wheatstone bridge : Electrical circuit with one unknown resistor.



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Mechanism :

- Piezoresistive strain gauges is used to complete the circuit.
- Wheatstone bridge is used to measure the unknown resistance (Of strain gauge).
- Resistance of unknown resistor is determined by pressure.



Components of arterial pulse waveform

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Components :

i. Systolic phase :

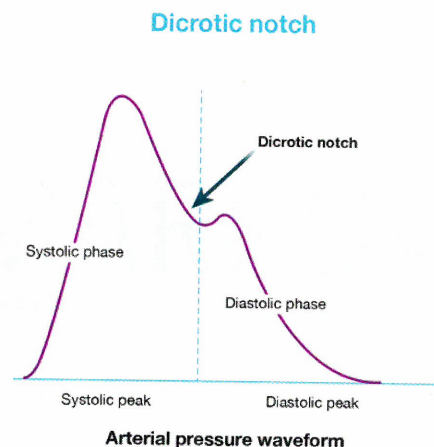
- Rapid increase in pressure to a peak.
- Begins with opening of aortic valve.
- Corresponds to LV ejection.

ii. Dicrotic notch :

Closure of aortic valve.

iii. Diastolic phase :

Run-off of blood into peripheral circulation.



Analysis :

- On ECG, R wave signals beginning of systole.
- Systolic upstroke does not occur immediately following systole. There is 160-180 millisecond delay.

